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Further evidence on the geographical concentration of venture capital investments

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Abstract This study provides an alternative examination into the dynamics of US venture capital investments across different geographical markets. A simple concentration index is developed to measure the size of venture capital investments by region relative to the US total venture capital investments. The time-series properties of this concentration index are examined; in particular, a series of unit root tests are employed to examine whether shocks to the index are temporary. Findings indicate that the geographical concentration of venture capital is increasing over time but shocks are temporary.

Keywords Venture capital investments · Regions · Shocks · Unit root tests · Concentration

JEL Classification G24 · R12 · C32

1 Introduction

Geographical concentration of firms is "more important than ever" (Clusterluck 2016) and urban economists have suggested innovative industries are characterized by significant localized agglomeration economies (Moretti and Wilson 2014). These economies result from a density of capital, research, intellectuals, communication networks, and/or geography. In fact, Florida and King (2016a, b) examine how venture capital investments are distributed across various regions in the US and globally. As venture capital investment is a key driver to new startups and economic development,

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it is important to understand the distribution of venture capital across regions. For example, Florida and King (2016a) find that venture capital investment is highly concentrated across just a few regions in the US. However, is venture capital investment becoming more or less concentrated across those regions over time? There is considerable evidence that diminishing returns to productive economic activities lead to convergence in economic growth across regions (Barro and Sala-i-Martin 1991; Higgins et al. 2006). This paper empirically examines the geographical concentration of venture capital over time.

There is much interest among regional economic developers to attract entrepreneurs and start-up firms to their respective area. However, the infrastructure investment necessary for innovative industries and related start-ups and entrepreneurs often comes from venture capitalists due to the risky nature of such firms. In particular, Batabyal (2010) examines the relationship between the entrepreneur and the financing entity that proposes the terms of the initial public offering. Entrepreneurial risk is multidimensional as Miles (2014) identifies eight risk factors including industry/economic forces, security dynamics, government, market forces, global forces, internal forces, business intangibles, and profit and inflation forces.

The active role that venture capitalists play in the operations of start-up firms lends itself to clustering around geographical areas (Feldman 1999; Samila and Sorenson 2010; Florida and King 2016a, b). While several papers have examined the types of firms that attract venture capital (Batabyal 2010; Bertoni et al. 2011; Gompers and Lerner 1998; Hellman and Puri 2000; Kolmakov et al. 2015; Rin et al. 2011), the relationship between venture capital and innovation (Kortum and Lerner 2000; Lerner 2002; Sleuwaegen and Boiardi 2014), and the time series or cyclical nature of venture capital investments (Ballinger et al. 2013; Gehrig and Stenbacka 2003; Ning et al. 2015), few papers have examined the geographical clustering of venture capital investments over time (Ballinger et al. 2016; Chen et al. 2010). Ballinger et al. (2016) used a battery of panel unit root tests to examine the time series properties of venture capital investments across 18 US regions. Their findings support convergence in that the (relative) venture capital investment shares are stationary.

This study provides further evidence of geographical concentration of venture capital investments by creating a concentration measure and examining the dynamics of that measure over time. Understanding the geographical distributional properties of venture capital investments by geography can assist investors with possible opportunities from a portfolio diversification perspective, while policymakers may be able to identify opportunities to attract venture capital for start-up firms and other entrepreneurial activities. The next section describes the venture capital investment data and methodology including the construction of the concentration measure.

2 Data, methodology, and results

The US venture capital investment (VCI) data is from Price Waterhouse Coopers Money Tree Survey and is categorized into one of the following 18 geographical areas: AK/HI/PR, Colorado, DC/Metroplex, LA/Orange County, Midwest, New England, North Central, Northwest, NY Metro, Philadelphia Metro, Sacramento, San Diego,

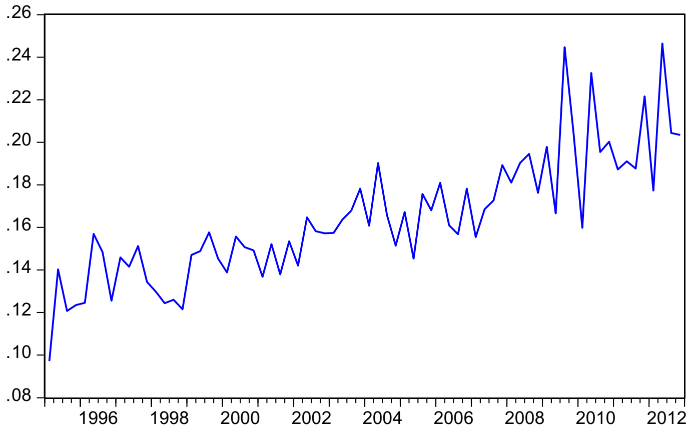

Fig. 1 Geographic concentration metric. *Notes*: Venture capital investment data are obtained from the Price Waterhouse Coopers Money Tree Survey. The concentration metric ranges in values of 0–1

Silicon Valley, South Central, Southeast, Southwest, Texas, Upstate NY.[1] The analysis uses quarterly observations of the dollar amount of VCI by 18 geographical regions over the time period of 1995–2012 and has been seasonally adjusted and deflated using the GDP price deflator to convert them to real 2009 dollars. The (geographical) concentration index is defined as the sum of the squares of the geographical market shares within the US and ranges between 0 and 1.[2] This index is essentially the same as the Simpson index or the Herfindahl–Hirschman index (HHI) and is often applied as a measure of competition within in an industry (Herfindahl 1950; Hirshman 1945, 1964; Simpson 1949). A major benefit to this index is that it takes into account the relative size distribution of the geographical areas: a larger share is weighted more than a smaller share. The index increases as the disparity in size between regions increases, that is, the more (geographically) concentrated the venture capital market, the higher the index value.

Figure 1 shows the concentration index over time. The index tends to fluctuate around some long-run upward trend. Based on this observation, it appears that the venture capital market is more concentrated rising from a value of 0.1 in 1995 to 0.2 in 2012. In analyzing market concentration in an industry using the HHI, the Department of Justice identifies a HHI between 0.15 and 0.25 as "moderately concentrated". By analogy, the VCI shares represented in Fig. 1 are moderately concentrated geographically. While the long term trend is upward, there is considerable variation around this trend. Unit root tests are necessary to determine if shocks (or unexpected changes) to the concentration metric are temporary or permanent.

Unit root tests examine if the index reverts back to its long-run trend following a shock. If the index has a unit root, then this result would indicate that the series is

[1] These 18 geographical areas capture all venture capital investments in the United States.

[2] The concentration measure, $CI_t = \sum_{i=1}^{18} VCI\ share_t^i$, where $VCIshare_t^i = VCI_t^i / total\ VCI_t$ and $i = \{18\ regions\}$.

unstable and does not revert back to the (long-run) trend following a shock. Alternatively, if the index is stationary, then this would indicate that the index is stable and would revert to its long-run trend following a shock. In order to examine the stationarity of the VCI (geographical) concentration index, several (common) unit root tests are employed. The augmented Dickey–Fuller (ADF) test (Dickey and Fuller 1979) is based on the ordinary least squares regression of Eq. (1).

$$\Delta CI_t = \rho_0 + (\rho_1 - 1)CI_{t-1} + \rho_2 t + \sum_{k=1}^{m} \delta_k \Delta CI_{t-k} + e_t \tag{1}$$

where CI_t is the concentration index of VCI shares across the geographical markets, Δ is the first-difference operator; t is a linear time trend, e_t is a covariance stationary random error and m is determined by Akaike's information criterion to ensure serially uncorrelated residuals. The null hypothesis is that CI_t is a nonstationary time series and is rejected if $(\rho_1 - 1) < 0$ and significant at the 5 percent level or less. The finite sample critical values for the ADF test developed by MacKinnon (1996) are used to determine statistical significance. The DF–GLS unit root test is also employed, which estimates the standard DF Eq. (1), but substitutes CI_t with the GLS detrended series.[3] Since the asymptotic distribution of the DF–GLS t-ratio differs from the DF distribution, the critical values provided by Elliott et al. (1996) are used.

Along with the DF and DF–GLS unit root tests, the Variance Ratio (VR) test is employed. If a series is a random walk, then the variance of a q-period difference should be q times the variance of the one-period difference. Lo and MacKinlay (1988, 1989) develop the variance ratio test allowing for general forms of heteroscedasticity and dependence, the hypothesis of which is referred to as the martingale null. The variance ratio, *VR(q)*, is thus defined as the ratio of the variance estimator at difference q to the variance of the first difference. A corresponding z-statistic is proposed that is asymptotically normal with mean zero and variance equal to one. However, since the variance ratio restriction holds for $q > 1$, Chow and Denning (1993) developed a joint variance ratio test that examines a set of multiple variance ratios statistics. In our analysis, we examine the variance ratios over one, two, and three year periods.

The KPSS test differs from the DF, DF–GLS, and the VR tests in that the relative concentration index is assumed to be (trend-) stationary under the null hypothesis. The KPSS unit root test statistic is obtained from the residuals by regressing CI_t on a constant and a trend. The KPSS statistic is defined as the Lagrange multiplier (LM) statistic:

$$KPSS = \left(T^{-2} \sum_{t=1}^{T} \hat{S}_t^2 \right) / \hat{\lambda}^2 \tag{2}$$

where $\hat{S}_t$ is the sum of the residuals on the regression, $\hat{\lambda}^2$ is the consistent estimate of the long-run variance, and T is the sample size. The critical values from the asymptotic distributions for the KPSS test statistic are provided in Kwiatkowski et al. (1992).

[3] Elliott et al. (1996) discusses the detrending procedure in more detail.

Table 1 Unit root tests

	Test statistic	*p* value	Order of integration
ADF	−10.331	<0.01	I(0)
DF–GLS	−8.3008	<0.01	I(0)
VR	3.265	<0.01	I(0)
KPSS	0.088	>0.10	I(0)

Table 1 reports the results of the battery of the four unit tests on the (geographical) concentration index. In terms of the ADF, DF–GLS, and VR tests, we reject the null hypothesis of a unit root in the concentration index. The results for the KPSS unit root test provide similar results as the other unit root tests. That is, the KPSS test fails to reject the null hypothesis of a (trend-) stationary process. Generally speaking, shocks to the concentration index are transitory in nature. In other words, the distributional properties of venture capital are stable and would revert to its long-run mean index following any shocks.[4]

3 Policy implications

The finding of (trend-) stationarity has several implications for regional policymakers. First, if venture capital investors unexpectedly shift their funding from one geographical market to another, then the relative share for that market would rise compared to the other markets. This investment adjustment, however, is only temporary. This finding is consistent with various economic models where economic resources have diminishing returns toward productive activities (Barro and Sala-i-Martin 1991, 1992; Higgins et al. 2006; Ballinger et al. 2016). It may be in regional policymakers' interest to stimulate this funding shift if the time lag to return to the mean is long enough. However, our results show that trend reversion occurs within three years which is unlikely to be sufficient. Second, these results suggest that policymakers can make use of historical data to understand the distributional properties of venture capital across different regions. Our finding that the distribution of venture capital is stable extends the work of Florida and King (2016a, b), which is also consistent with Moretti and Wilson (2014) who find " limited evidence of a first-mover advantage for biotech incentives" (p. 21). First mover advantages in providing incentives would be persistent in the presence of agglomeration economies as the initial positive effect of the incentive would keep agglomerating after other states (regions) have matched the incentive. Third, given the recent level of our concentration ratio of 0.2, this may start ringing alarm bells in policymakers' ears. If this was a HHI for an industry it would be considered moderately competitive by the Department of Justice. However, Matsumoto et al. (2012) have shown that in certain circumstances the HHI fails to detect cooperation.

4 Silicon Valley has the largest share of the venture capital market and excluding this region will change the concentration ratio and its overall interpretation. However, the distributional properties of venture capital (across the remaining regions) tend to be similar in that shocks to the (adjusted) index are transitory in nature.

In the case where cooperating firms have identical marginal costs, the increase in HHI indicates cooperation. It seems plausible that in an agglomeration economy firms may cooperate at least implicitly. For example, a new venture spun off from an existing company may receive support as a startup. Future research should endeavor to determine the exact nature of this relationship and its impact on geographical concentration of VCI.

4 Concluding remarks

This study uses a concentration measure to explain the geographical distribution of venture capital investments over time. Next, a battery of unit root tests were employed to examine the time series properties of the concentration measure. The results indicate that the metric is increasing over time but (trend-) stationary. Shocks to the distribution of venture capital investments across regions are only temporary as the distribution is mean reverting. Thus, the (geographical) concentration measure is not time dependent.

Our results also lead to another implication with relevance to the venture capital market literature regarding time series estimates of VCI distributions among regions. Our findings suggest that policymakers' attempts to attract VCI may just be temporary without a fundamental restructuring of the regional economy. There is a need for further research on how firms compete and cooperate within agglomeration economies.

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